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(NASA-CR-161637) STABILIZED ZEEMAN SPLIT  
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for  
STABILIZED ZEEMAN SPLIT LASER  
by  
TAI CORPORATION  
Contract NAS8-34036

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## 1.0 INTRODUCTION

This report summarizes the engineering and development work performed by TAI Corporation under Contract NAS8-34036 for a stabilized Zeeman split laser for use in a polarization profilometer needed for the AXAF program.

## 2.0 PURCHASED EQUIPMENT

Initial effort was the purchase of one Hewlett-Packard Zeeman laser model 5501A, two Hewlett-Packard Detectors model 10780A and one Hewlett-Packard Phase Meter model 3575A with options 001, 003 and 908.

## 3.0 LASER MODIFICATION

After receipt of the Hewlett-Packard equipment, the laser was modified to stabilize the Zeeman split beat-frequency thereby increasing the phase measurement accuracy from the Hewlett-Packard 3 degrees to an accuracy of .01 degrees.

### 3.1 Inductive Winding

Enameled magnet wire (size 26) was used to wind a two-layered (113 turns per layer) inductive winding over the magnet surrounding the laser plasma tube of the HP 5501A. The two-layered winding has an inductive value of approximately 1.0 millihenry. Figure 1 shows the Zeeman frequency change in KHz resulting from coil current changes.

### 3.2 Phase-Lock

The addition of the two-layered inductive winding converts the laser to a current-controlled oscillator whose frequency is linearly related to coil current. This linear relationship between coil current and laser frequency permits phase-locking the laser frequency to a stable crystal controlled reference frequency.

Figure 2 shows the relative instability of the Zeeman frequency over a period of eight hours without phase-lock, whereas Figure 3 shows the stability achieved with phase-lock -- less than 6 Hz variation in 24 hours. This is an improvement of over 10,000 when compared to the condition without phase-lock.

FIGURE 1

ZEEMAN FREQUENCY CHANGE  
VS. COIL CURRENT

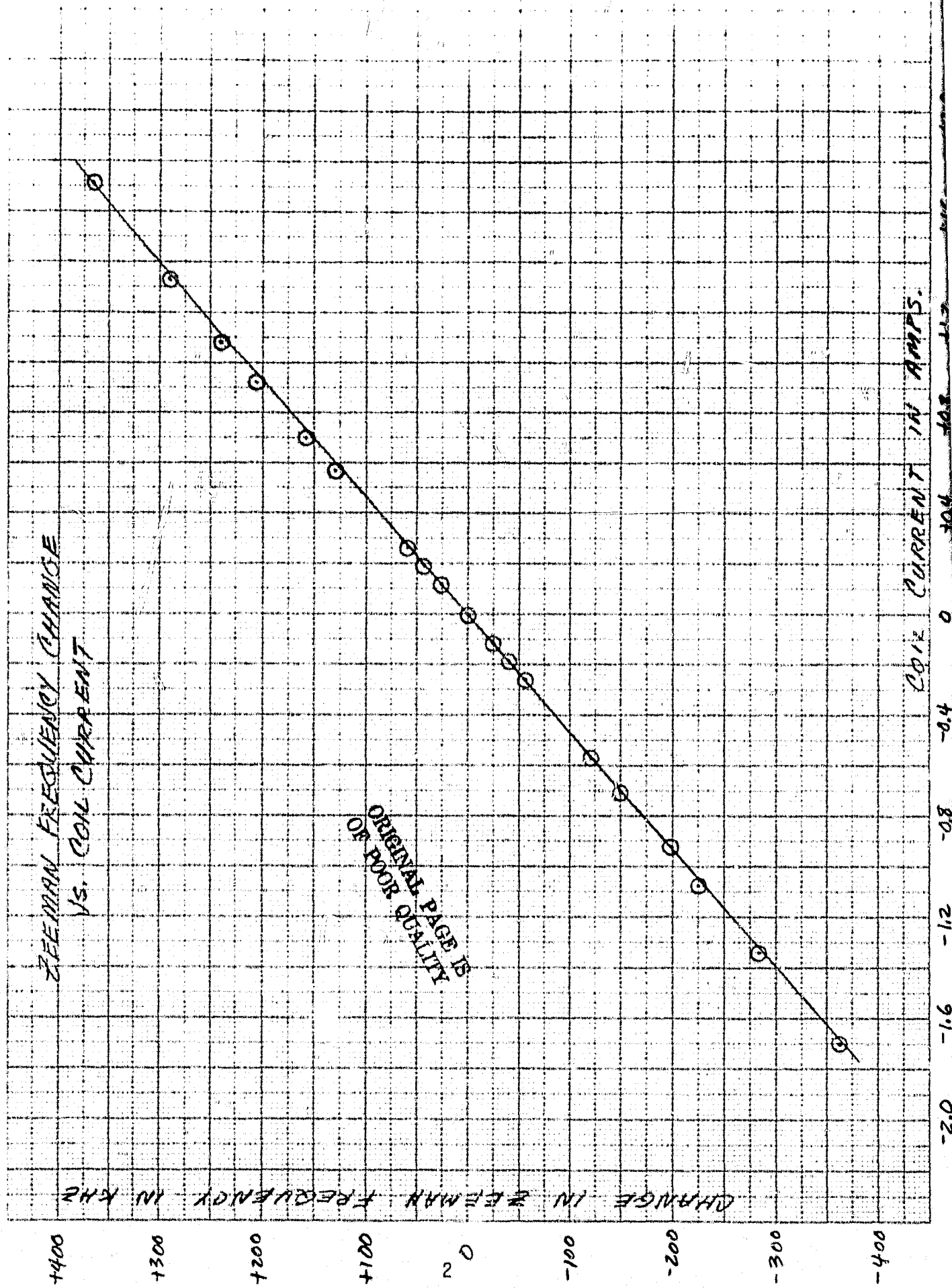
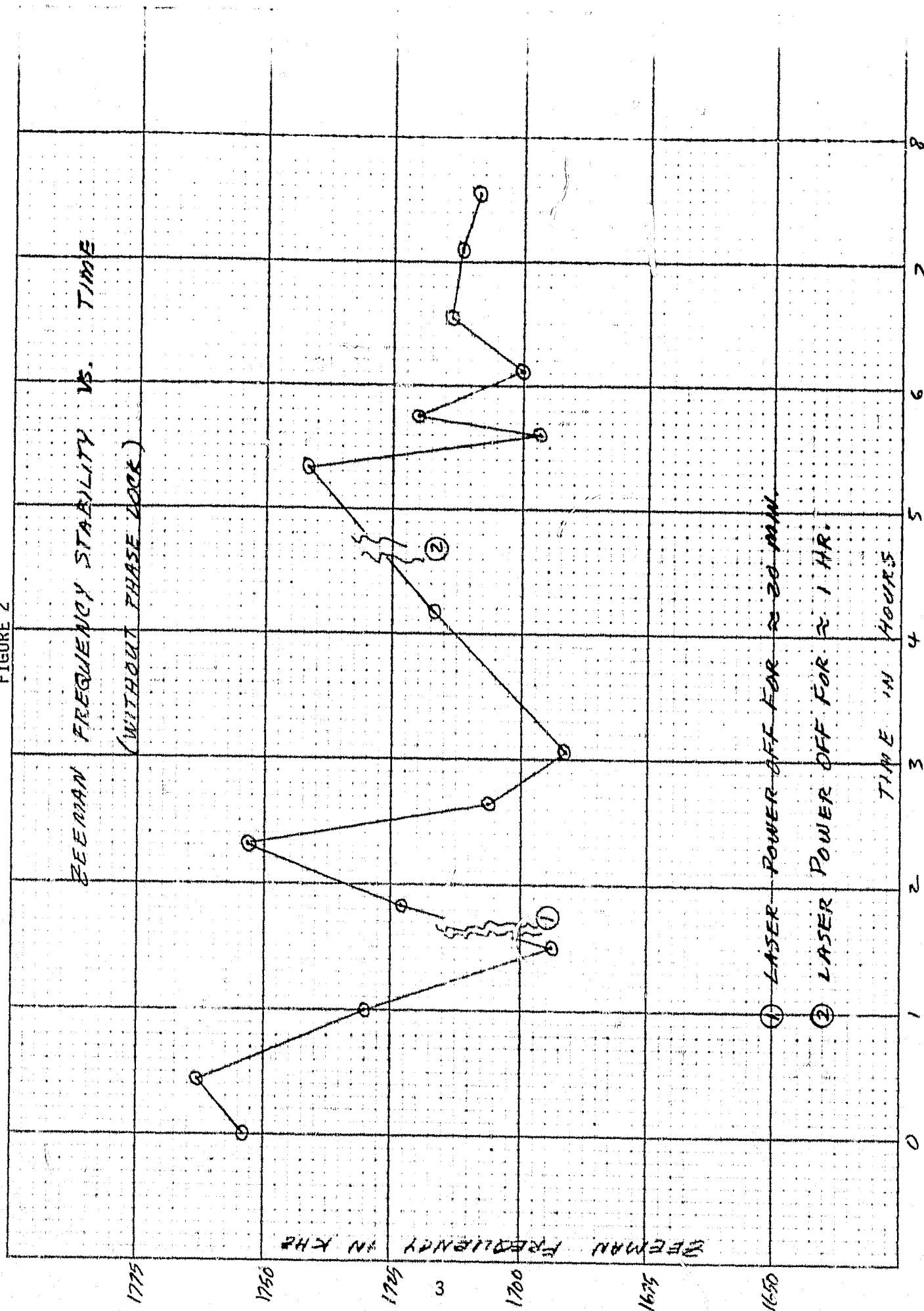
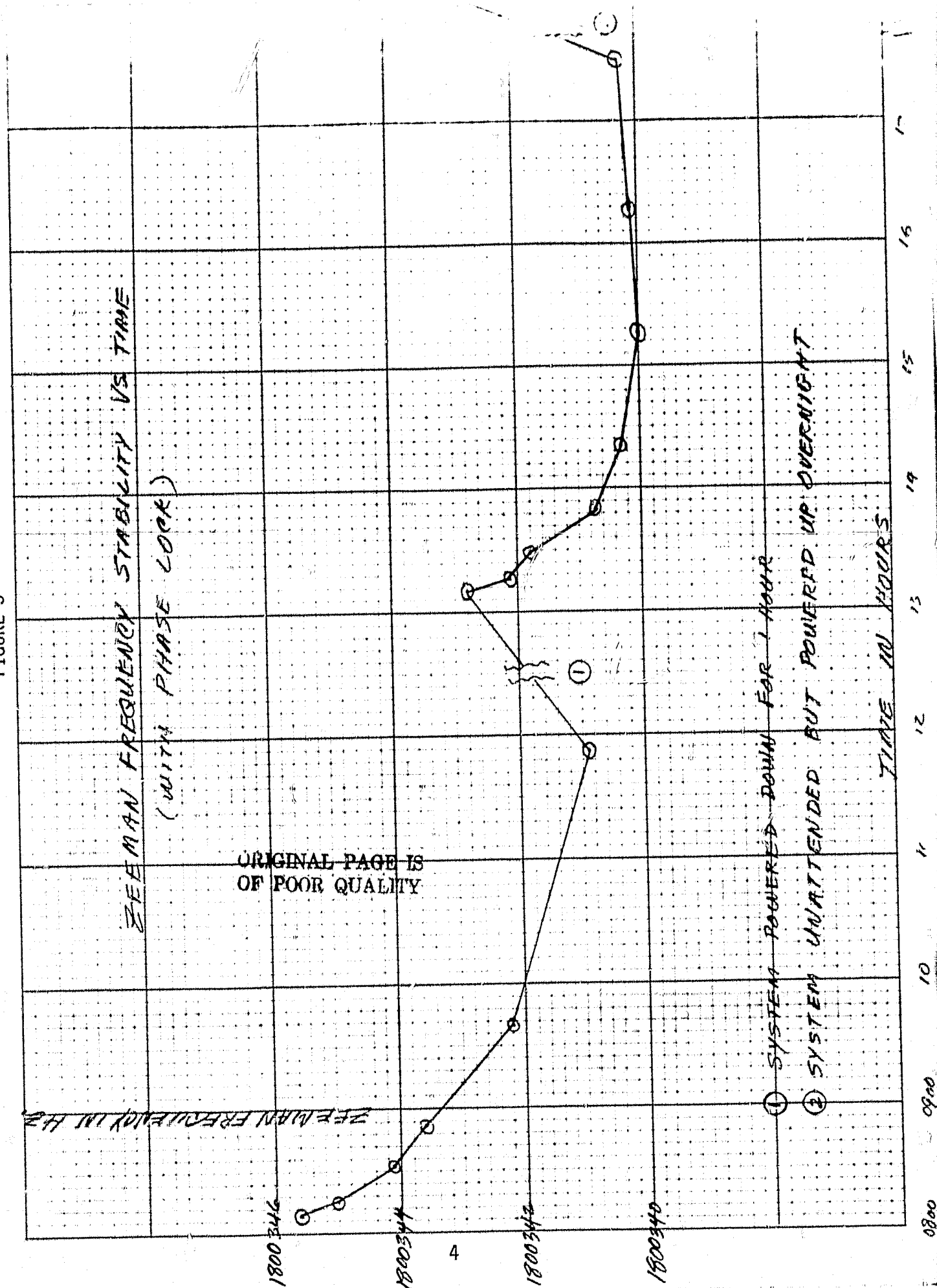


FIGURE 2



**FIGURE 3**



#### 4.0 TAI FEASIBILITY BREADBOARD

Figure 4 shows, in block diagram format, the arrangement of equipment used to demonstrate stability and resolution sufficient to read surface irregularities to 0.1nm. The quarter-wave plate simulates angular phase shift caused by surface irregularities. The neutral density filter is used only to control the signal amplitude of the measurement detector. The quarter-wave plate was mounted to permit a very fine angular adjustment of one degree by means of a vernier control. Varying the wave plate angle in one degree increments produced a corresponding phase shift which was read on the PHASE Display. Table 1 shows the phase change for twenty different angular settings of the quarter-wave plate.

These data were obtained with the system mounted on a rigid table. Normally the laser, detectors and all optical components would be mounted on an air-bearing isolated table. The readings were observed on a sensitive null-type analog voltmeter connected to the A/D output.

#### 4.1 Observed Instability

The DC voltage (during early stages of system warm-up) seemed to contain a slow oscillatory component. This oscillation decreased in amplitude and increased in period in direct proportion to the time period equipment was energized. The readings of Table 1 were made after the system had been energized over night. The voltmeter was observed to drift from a reference point down to the equivalent of 0.15 nM and return over a period of about 6 minutes. In the next 4 minute period the reading moved up to 0.12 nM and then moved down and dwelled between 0.5 and 0.2 nM for the next 10 minutes. During these observations faster fluctuations of about 0.02 nM were observed on the voltmeter.

Table 1. Comparison of Phase Shift vs Angular Change

Wave Plate Angle	Phase
260°	61.3 nM
261	58.7
262	55.6
263	52.7
264	49.5
265	46.6
266	43.4
267	40.3
268	37.2
286	- 6.1
287	- 8.1
288	-10.0
289	-12.0
290	-13.9

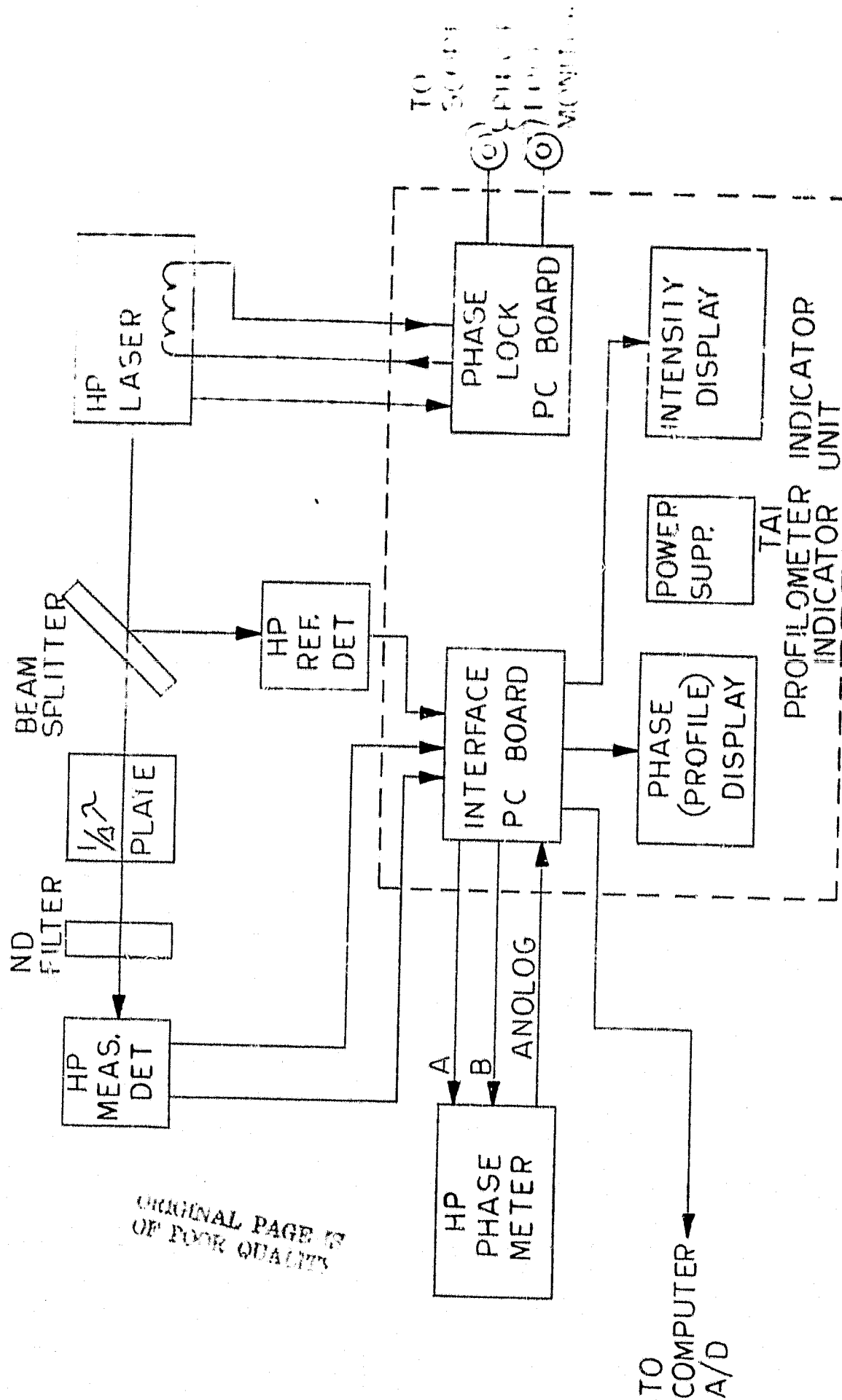


FIGURE 4. SYSTEM FUNCTION BLOCK DIAGRAM

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OF POOR QUALITY

(Continued)

Table 1. Comparison of Phase Shift vs Angular Change

Wave Plate Angle	Phase
291	-15.8
292	-17.8
293	-19.7
294	-21.6
310	-57.0
315	-74.1

The slow oscillatory component was probably caused by the structural warm-up within the laser itself, but this could not be proven. The faster fluctuations can probably be eliminated with an air-bearing isolation table.

4.2 That Portion of Figure 4 Enclosed by Heavy Dashed Lines Represents the Circuitry Developed by TAI to:

- 1 - Provide power to the system.
- 2 - Phase-lock the laser to a stable reference frequency.
- 3 - Provide an interface between the phase meter and the computer's analog-to-digital converter permitting adjustment of gain so that the least-significant-bit (5.0 mv) represents 0.1 nm surface irregularity.
- 4 - Display on the PHASE meter a reading (in nanometers) of the phase difference between the reference (REF) and measurement (MEAS) detectors when adjusted to read surface irregularities in 0.1 nm.
- 5 - Display on the INTENSITY meter a voltage value proportional to the intensity of the beam received by the MEAS detector.

5.0 ASSEMBLY AND PREPARATION FOR USE

The stabilized Zeeman split-laser profilometer should be assembled on optical bench or other surface that is isolated (air-bearing suspension) from earth vibrations.

5.1 Interconnection of Equipment

Interconnect the equipment as shown in Figure 5.

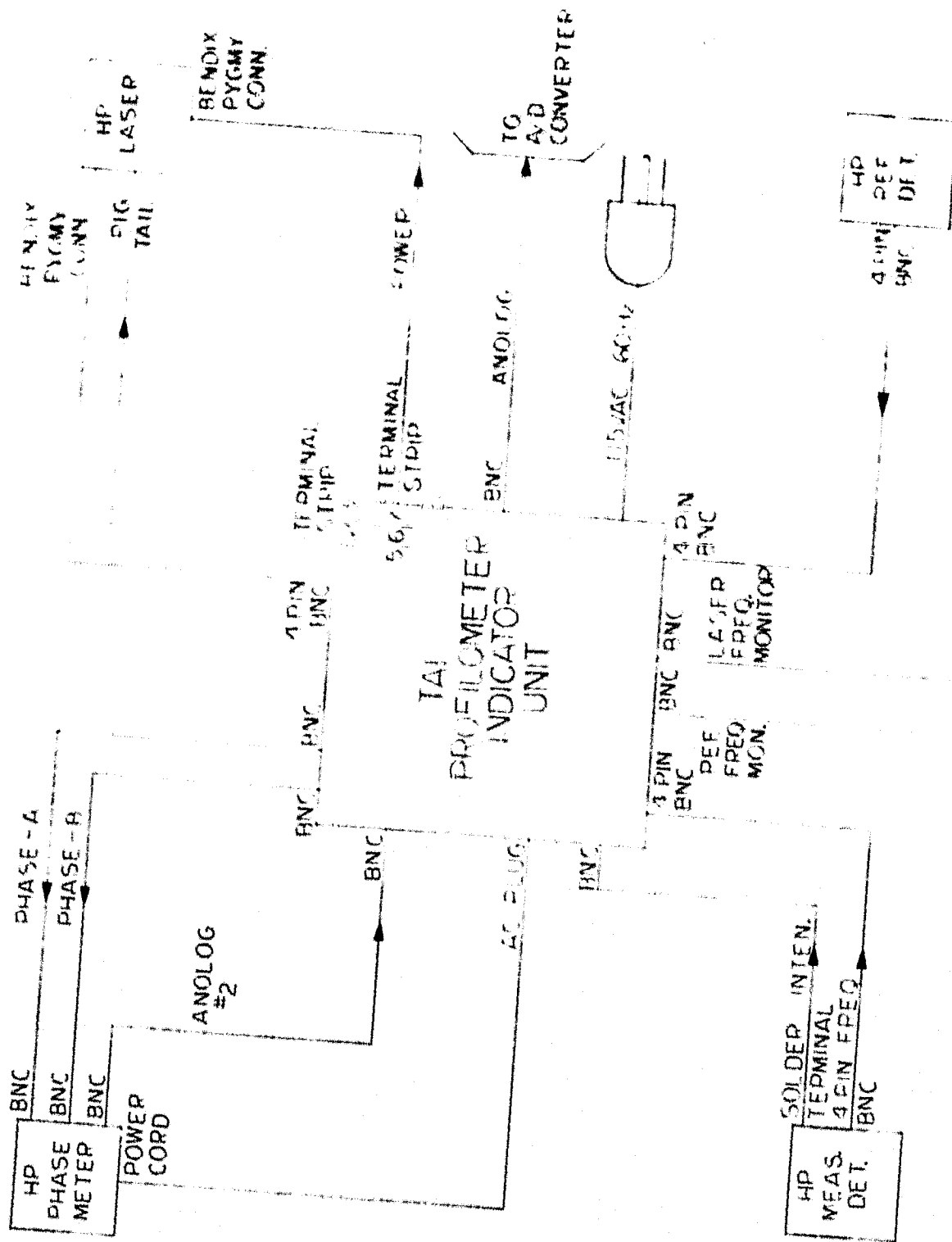


FIGURE 5. SIMPLE SYSTEM INTERCONNECT DIAGRAM

## 6.0 EQUIPMENT OPERATION

With equipment interconnected as shown in Figure 5, power is applied to the system through the key-operated power switch.

### 6.1 Phase-Lock

After power is applied observe the "Coil Current Meter" mounted on the front panel of the TAI Profilometer Indicator Unit. Coil current will normally increase slowly, then stabilize when phase-lock is achieved. Occasionally phase-lock will not be achieved as coil current increases. Instead, the coil current will approach full-scale reading, then start decreasing in value and phase-lock will occur with decreasing current.

### 6.2 Phase-Lock Failure

Failure of the circuit to phase-lock is indicated by (1) no coil current; (2) excessive coil current [near full scale reading]; or (3) drifting coil current. Phase-lock may be observed on a dual-trace oscilloscope by using the two BNC connectors mounted on the front panel of the TAI Profilometer Indicator Unit (PIU).

#### 6.2.1 Corrective Action

If phase-lock failure occurs disconnect the laser coil (terminals 1, 2 and 3 of TAI PIU terminal board). Then connect a frequency counter to the Laser Frequency Monitor BNC on the PIU front panel. The frequency of the laser should be between 1600 and 1800 KHz. If the frequency is above 1800 KHz replace the crystal.

##### 6.2.1.1 Crystal Replacement

Two crystals are supplied with the equipment. One is mounted on the component side of the phase-lock P.C. board in a crystal holder and is ground to produce a frequency of 1800 KHz. The second crystal is ground for 1840 Hkz and is attached to the P.C. board by lacing cord.

If the laser frequency is too high (above 1800 KHz) phase-lock cannot occur because the reference (crystal) frequency is too low. Anticipating the improbably condition where the normal 1600-1800 Khz natural Zeeman frequency drifts higher due to unknown condition, phase-lock may be re-established by using the second higher frequency crystal.

##### 6.2.1.2 Phase Jitter

With a dual trace oscilloscope connected to the REF and MEAS frequency monitor BNC connectors, adjust R-17 (mounted on the phase-lock P.C. board) while observing the phase-lock on the scope. Normal jitter covers about 20% of the waveform period. Adjust R-17 for minimum jitter. If R-17 is over-adjusted, phase-lock may be broken. This will be indicated by a rapid rise or fall in coil current. To re-establish phase-lock thrn R-17 in the opposite direction to that which produced broken phase-lock.

### 6.3 Calibration

Each user of the stabilized Zeeman split laser profilometer will be required to develop custom calibration procedures suitable to the intended use of the equipment.

#### 6.3.1 Phase-Lock Profile Adjustment

Potentiometer R-8 mounted on the Interface P.C. board changes the gain of the circuit to accommodate custom calibration. This gain potentiometer is used to adjust the PHASE panel meter reading down to 0.1 nm.

#### 6.3.2 Analog/Digital LSB Adjustment

Potentiometer R-10, mounted on the Interface P.C. board changes the gain of the circuit to accommodate custom calibration. This gain potentiometer adjusts the output of the A/D Converter so that the Least-Significant-Bit (LSB) will meet calibration requirements down to 0.1 nm.